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The impact of heart rate variability on subjective well-being is mediated by emotion regulation

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ABSTRACT

Resting heart rate variability (HRV) can serve as an index of self-regulatory strength. In the present study we tested the hypotheses that HRV, indexing adaptive self-regulation, is associated with subjective well-being, and that this association is mediated by the habitual use of strategies of emotion regulation that involve executive functions. In addition to measuring heart rate at rest, subjective well-being – as indicated by positive habitual mood and satisfaction with life – and habitual emotion regulation were assessed via self-reports. The findings were largely consistent with our predictions. HRV was positively associated with cheerfulness and calmness, and these effects were mediated by executive emotion regulation. Mediated by these strategies, HRV was also associated with satisfaction with life. Together, the results support the use of HRV as an index of self-regulatory strength.

1. Introduction

Self-regulatory strength, defined as the ability to exert self-control and to override or alter one's dominant response tendencies (Baumeister & Heatherton, 1996), is a major prerequisite for adaptive behavior, such as regulating emotions, persisting in the face of failure, or adopting positive health behavior (Schmeichel & Baumeister, 2004; Tangney, Baumeister, & Boone, 2004).

In previous research, heart rate variability (HRV) was found to serve as a physiological index of self-regulatory strength (Segerstrom & Solberg Nes, 2007). As the ability to exert self-control predicts a broad range of positive outcomes, such as academic and interpersonal success (Tangney, Baumeister, & Boone, 2004), it seems reasonable to expect HRV to be associated with subjective well-being (SWB). SWB refers to well-being from the people's own perspective. It includes both cognitive judgements of satisfaction with life and affective evaluations of pleasant and unpleasant affect. Theories of SWB emphasize the interaction of life circumstances with physical health and psychological factors, such as personality traits, goal attainment and coping, in producing SWB (e.g., Diener, Suh, Lucas, & Smith, 1999). The assumption that HRV is associated with SWB was indirectly supported by a study showing an inverse relationship between perceived emotional stress and HRV (Dishman et al., 2000). However, empirical evidence for the relationship between HRV and subjective well-being has been surprisingly rare. Addressing this gap, the present study examined whether trait HRV is associated with subjective well-being, as indicated by positive habitual mood and satisfaction with life. Moreover, we tested the hypothesis that the association between HRV and subjective well-being is mediated by strategies of emotion regulation that reflect self-regulatory strength. More specifically, based on the assumption that adaptive self-regulation relies on the capacity to exert control over cognitions, emotions, behavior, and physiology (Solberg Nes, Roach, & Segerstrom, 2009; Thayer, Hansen, Saus-Rose, & Johnsen, 2009), we expected HRV to be related to cognitive strategies of emotion regulation that involve executive functions, such as reasoning, generating, and following through with goals and plans (Suchy, 2009).

1.1. Heart rate variability (HRV)

The Neurovisceral Integration Model (Thayer et al., 2009) provides a theoretical rationale for explaining the role of HRV as an index of self-regulatory strength. Within this model, which outlines the associations among different self-regulatory processes, the central autonomic network (CAN) is assumed to adjust physiological arousal to changing situational demands and thus to support goal-directed behavior and adaptation. The primary output of the CAN is mediated through sympathetic and parasympathetic (vagus nerve) neurons that innervate the heart. The interplay of these inputs with the cardiac sinoatrial node produces variability in the heart rate (HR) time series. Thus, the output of the CAN is directly linked to HRV, the beat-to-beat variation in heart rate. Especially high-frequent, vagal mediated tonic HRV is thought to

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be a peripheral proxy for regulatory strength (Thayer & Friedman, 2002). In addition, sensory information from peripheral end organs such as the heart and the immune system are fed back to the CAN. As such, HRV is an indicator of central nervous and autonomic nervous system integration. Thayer et al. (2009) propose that the CAN and other functional units within the central nervous system represent a common central functional network that is associated with processes of response organization and selection and serves to control psychophysiological resources in attention and emotion. The ability to meet changing environmental demands depends on the functioning of this central functional network.

Empirical evidence strongly supports these assumptions, indicating that HRV covaries with processes that are involved in self-regulation, such as emotion regulation (Appelhans & Luecken, 2006), constructive coping (Fabes & Eisenberg, 1997), and the pursuit of goals (Geisler & Kubiak, 2009). More specifically, previous research has indicated that HRV is associated with behaviors that require executive functioning. For example, positive associations were found between resting levels of vagally mediated HRV and performance on working memory tests and a continuous performance test (Hansen, Johnsen, & Thayer, 2003), whereas negative associations were found between waking HRV and frequency and duration of worrying (Brosschot, Van Dijk, & Thayer, 2007). Further support for the use of HRV as a proxy for regulatory strength comes from neurobiological research indicating a link between HRV regulation and prefrontal cortical activity, which is a key structure for executive functioning (Lane et al., 2009). High short-term retest reliability (Kautzner, 1995) and moderate stability over time (Rottenberg, Wilhelm, Gross, Biuckians, & Gotlib, 2001; Salomon, 2005) as well as correlations with temperament (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996) and evidence for the heritability of a substantial proportion of variance in HRV (Singh et al., 1999) suggest that HRV can be conceptualized as a traitlike factor.

1.2. Executive function and emotion regulation

Strategies for emotion regulation can be distinguished along different dimensions, such as the time point targeted by a strategy within the process of emotion regulation (Gross & Thompson, 2007). Another possible way to characterize strategies of emotion regulation is by whether they involve mechanisms that reflect executive functioning (Zelazo & Cunningham, 2007). According to Zelazo and Cunningham, executive function includes higher cognitive processes that are involved in goal-directed problem-solving, such as problem representation, planning, execution, and evaluation. In their view, at an algorithmic level executive function can be characterized by the ability to formulate a rule system, maintain it in working memory, and then act on the basis of the rule systems. Executive function encompasses mental set shifting, information updating and monitoring, and inhibition of prepotent responses (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

Strategies of emotion regulation that reflect executive function are, for example, reappraisal or refocusing that imply mental shifting, and planning that involves information updating and monitoring. By contrast, other strategies of emotion regulation appear to be associated with deficits in executive functioning. For example, depressive rumination, a response to dysphoric mood that is characterized by recurrent thoughts focusing on the causes, symptoms, and implications of one's depressive mood (Nolen-Hoeksema, 1991), was found to be related to attentional inflexibility (Davis & Nolen-Hoeksema, 2000) and inhibitory deficits (Whitmer & Banich, 2007).

In previous research, cognitive strategies of emotion regulation that involve executive mechanisms, such as positive reappraisal, were found to be associated with higher subjective well-being (Shiota, 2006), whereas rumination that reflects deficits in executive functioning, was found to exacerbate depressive mood (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Given that HRV can be expected to be associated with the habitual use of emotion regulation strategies that involve executive processes, we tested the hypothesis that these strategies mediate the association between HRV and subjective well-being.

2. Method

2.1. Participants

Participants ($N = 172$, 76% women, age $M = 23$ years, $SD = 4$) were psychology and non-psychology students. They either (a) received course credit for participation, (b) took part in a lottery for a book coupon, or (c) were paid five Euros. Participants filled out questionnaires that assessed subjective well-being (mood and satisfaction with life), and habitually employed emotion regulation strategies. In addition, their heart rate was measured.

2.2. HRV

We measured heart rate at rest for 7 min via the heart rate monitoring system Polar RS800CX (Polar Electro Oy, Kempele, Finland). During measurement, participants sat still by themselves without any task since parasympathetic influences predominate at rest. Using the Polar Precision Performance™ Software, we preprocessed sequential interbeat intervals for artefacts. A visual screening for artefacts followed. We then used the HRV Analysis program (Niskanen, Tarvainen, Ranta-aho, & Karjalainen, 2004) to perform a frequency-based technique of power spectral analysis (autoregressive modeling technique) to extract high-frequency components, 0.15–0.4 Hz, which primarily reflect cardiac parasympathetic influence from sequential interbeat intervals. The absolute value of power was chosen as unit (ms^2). With this procedure, we followed the recommendations of the American Heart Association (Task Force, 1996). In a previous study, in which heart rate was measured the same way, we obtained a considerably high retest-reliability coefficient over about 1 h ($r = .70$, Geisler & Kubiak, 2009).

2.3. Self-report scales

2.3.1. Mood

Habitual mood was measured by the *UWIST Mood Adjective Check List* (Matthews, Jones, & Chamberlain, 1990; German adaptation Hermanns, Kubiak, Kulzer, & Haak, 2003). The *UWIST Mood Adjective Check List* contains six subscales measuring positive and negative hedonic tone (cheerful vs. dissatisfied), tense arousal (calm vs. anxious), and energetic arousal (vigorous vs. tired). Participants rated on a 9-point scale ranging from 1 "not at all true" to 9 "totally true" how they felt in general. Each subscale consists of four items; scale scores were computed by summing the respective item scores. Cronbach's α ranged from .78 to .93.

2.3.2. Satisfaction with life

We employed the *Temporal Satisfaction with Life Scale* to assess past, present, and expected future life satisfaction (Pavot, Diener, & Suh, 1998; German adaptation Trautwein, 2004). Item scores ranged from 1 "not at all true" to 4 "totally true". Each subscale consists of four items; scale scores were computed by summing the respective item scores. Higher scores indicate greater satisfaction with life. Cronbach's α ranged from .80 to .89.

2.3.3. Emotion regulation strategies

Cognitive emotion regulation strategies were assessed with two self-report instruments. (1) The *Cognitive Emotion Regulation*